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(54) Abstract Title
Displacement measuring apparatus

(57) A displacement measuring apparatus comprises a scale member having scale gratings and a sensor head for reading the scale gratings. The sensor head includes an LED, an index scale for transferring output light from the LED to the scale member, and a photodetector array (5) for detecting modulated light from the scale gratings to output displacement signals. The photodetector array (5) includes a first photodetector group (51a) formed in a semiconductor thin film on a transparent substrate (50); an insulator (24) covering the first photodetector group (51a); and a second photodetector group (51b) in a semiconductor thin film disposed on the insulator (24), for receiving transmitted lights through spaces between photodetectors in the first photodetector group (51a). Alternatively the two groups of detectors may be replaced by optical waveguides that collect light reflected from the scale grating and direct it to detector arrays via optical fibres, or by two arrays of capacitor sensors or inductive coil sensors.

FIG. 2B

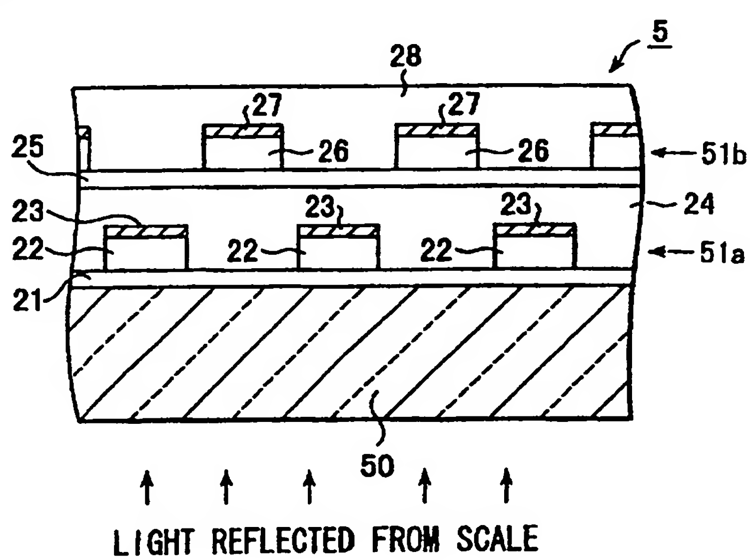

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FIG. 1A

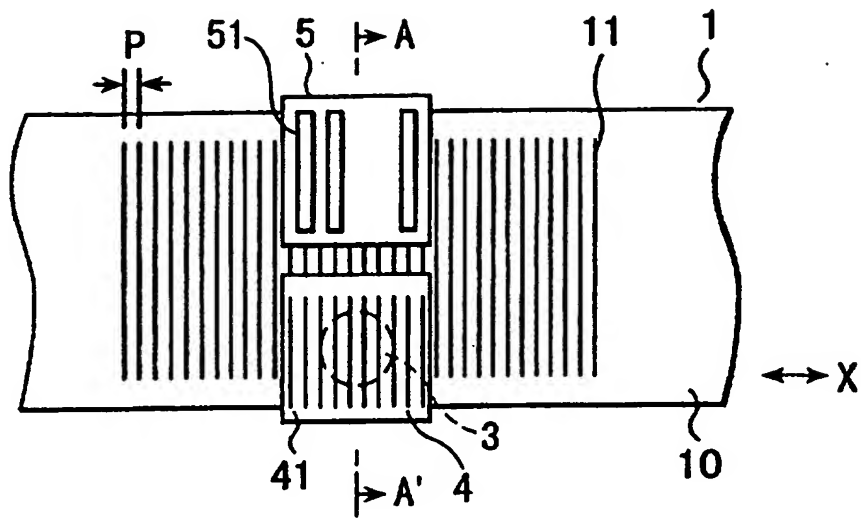


FIG. 1B

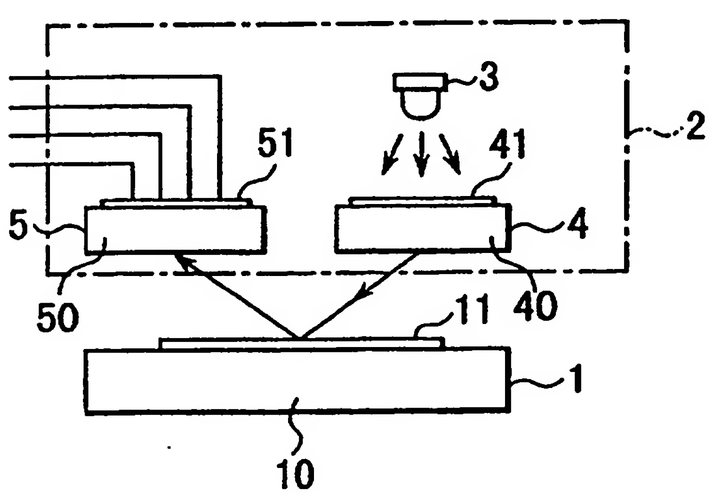


FIG. 2A

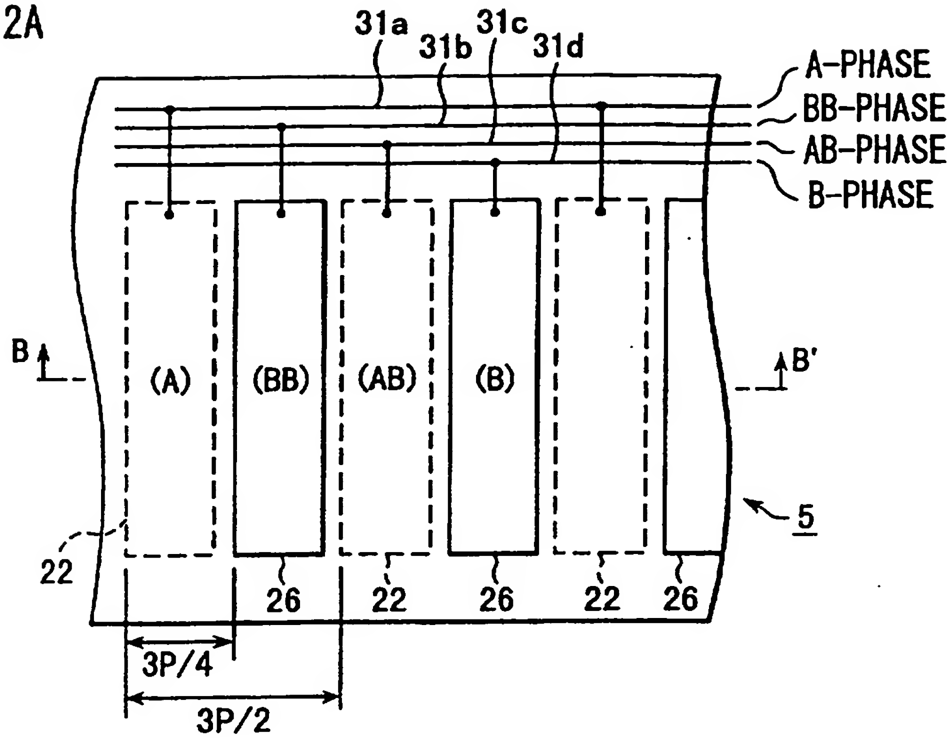
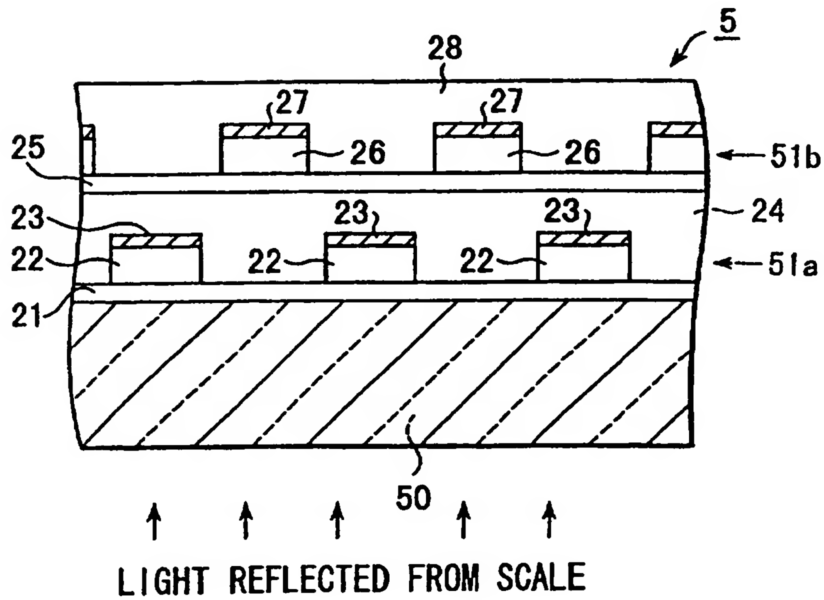
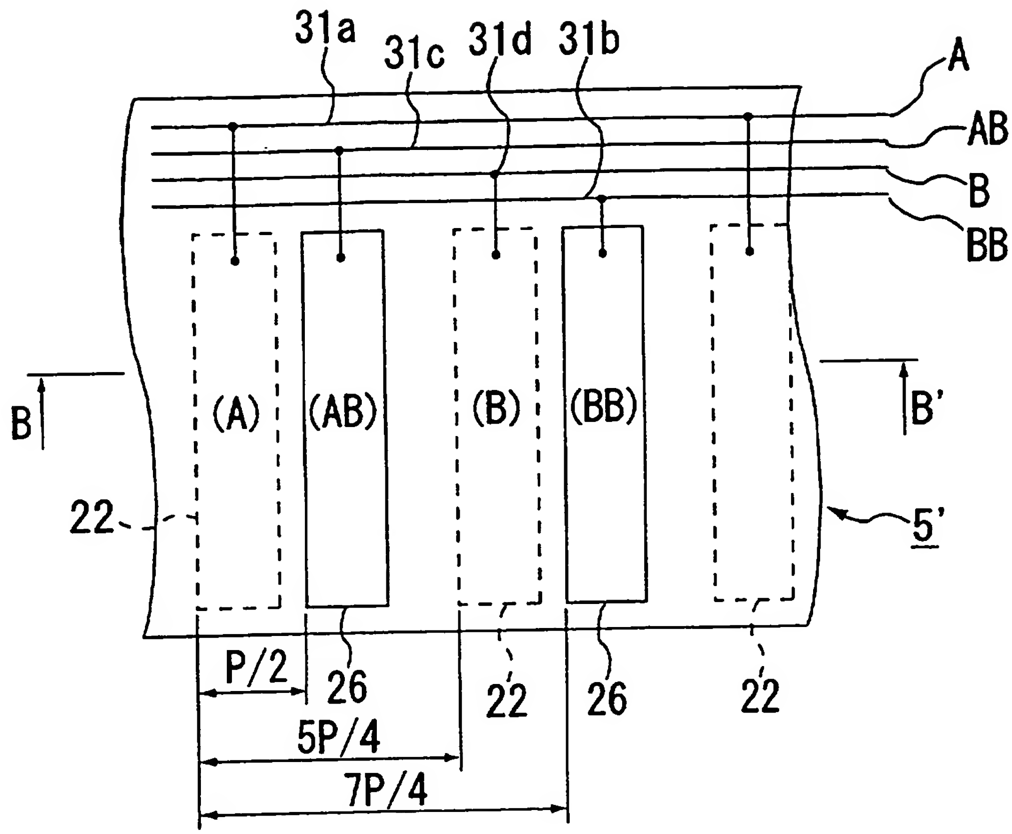

31a
31b
31c
31d
A-PHASE
BB-PHASE
AB-PHASE
B-PHASE
B
B'
(A)
(BB)
(AB)
(B)
5
22
26
22
26
22
26
3P/4
3P/2

FIG. 2B


5
28
27
27
25
26
26
51b
23
23
23
24
22
22
22
51a
21
50
LIGHT REFLECTED FROM SCALE

F I G. 2C


31a
31c
31d
31b
A
AB
B
BB
B
B'
(A)
(AB)
(B)
(BB)
22
5'
P/2
26
22
26
22
5P/4
7P/4

F I G. 2D

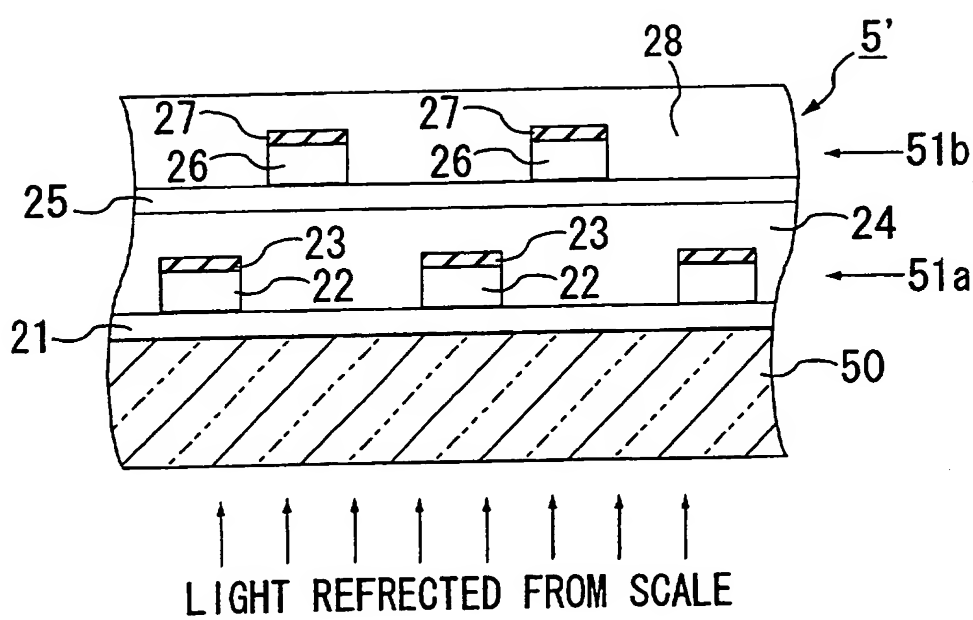

28
5'
27
26
27
26
51b
25
24
23
22
23
22
51a
21
50
LIGHT REFRECTED FROM SCALE

FIG. 3

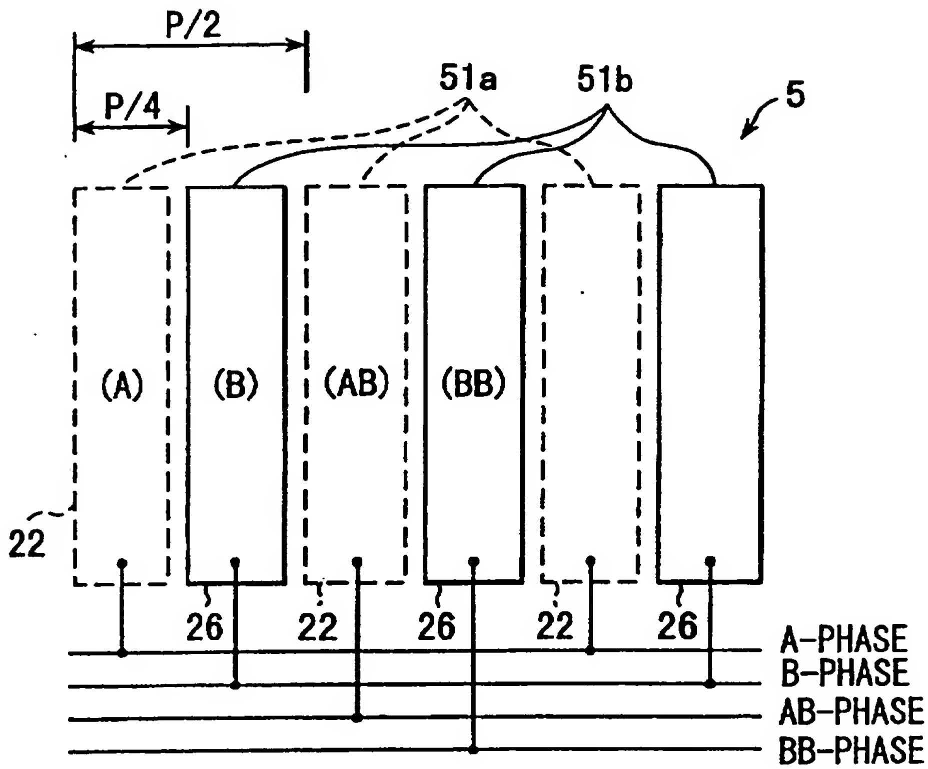

P/2
P/4
51a
51b
5
(A)
(B)
(AB)
(BB)
22
26
22
26
22
26
A-PHASE
B-PHASE
AB-PHASE
BB-PHASE

FIG. 4

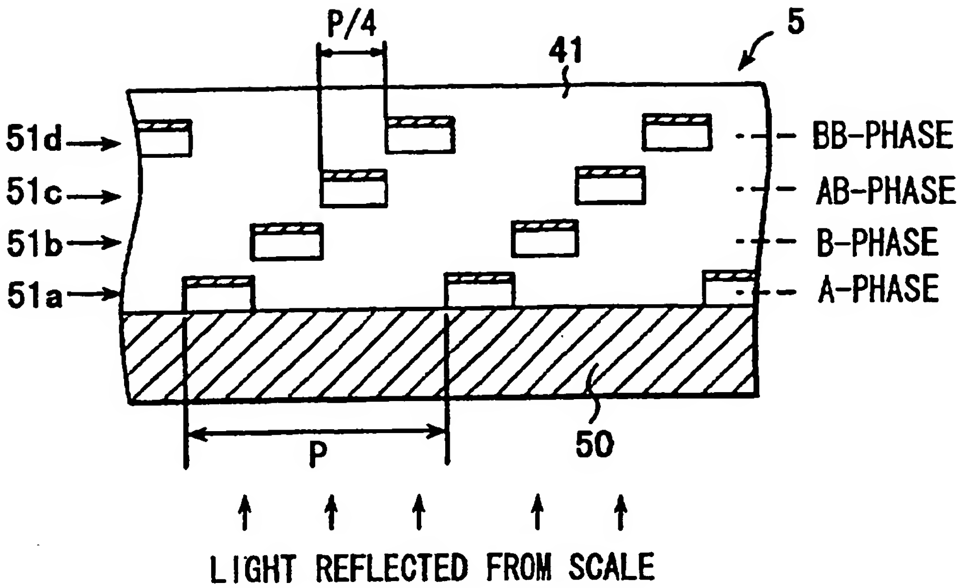

P/4
41
5
51d
51c
51b
51a
BB-PHASE
AB-PHASE
B-PHASE
A-PHASE
P
50
LIGHT REFLECTED FROM SCALE

FIG. 5

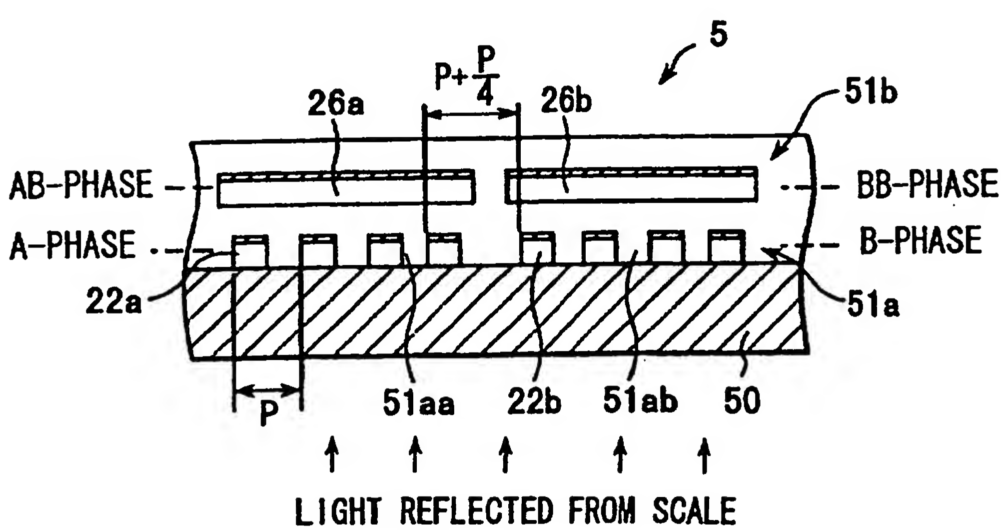

5
P+P/4
26a
26b
51b
AB-PHASE
BB-PHASE
A-PHASE
B-PHASE
22a
51a
P
51aa
22b
51ab
50
LIGHT REFLECTED FROM SCALE

FIG. 6

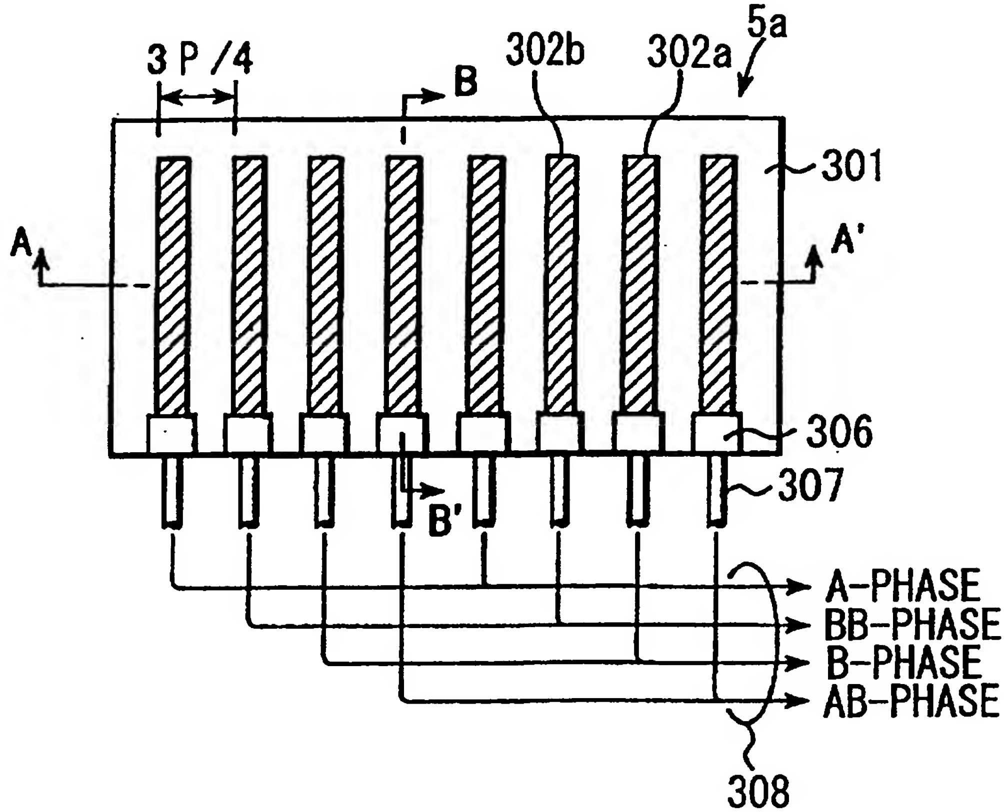

3P/4
B
302b
302a
5a
301
A
A'
306
307
B'
A-PHASE
BB-PHASE
B-PHASE
AB-PHASE
308

FIG. 7A

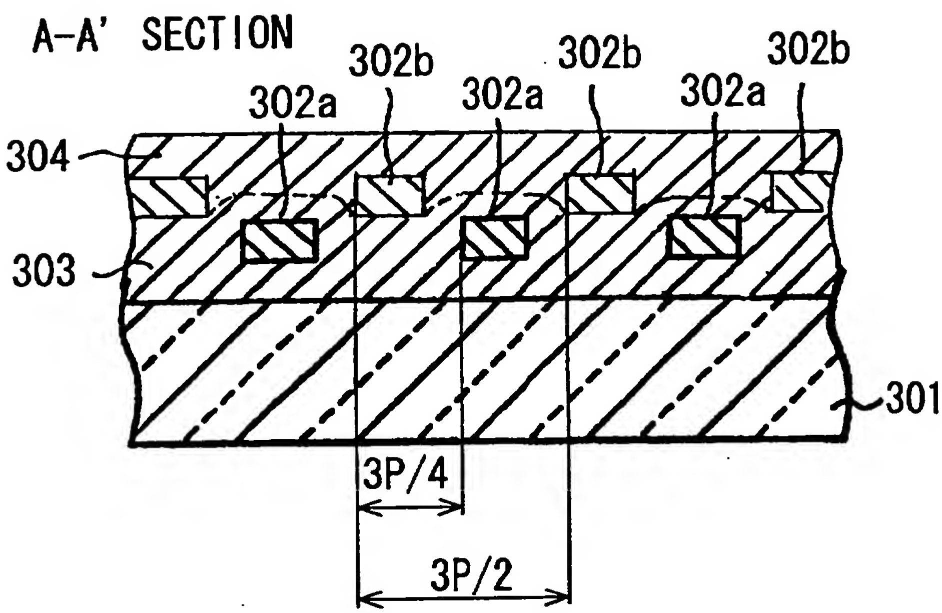

A-A' SECTION
302b
302b
302b
302a
302a
302a
304
303
301
3P/4
3P/2

FIG. 7B

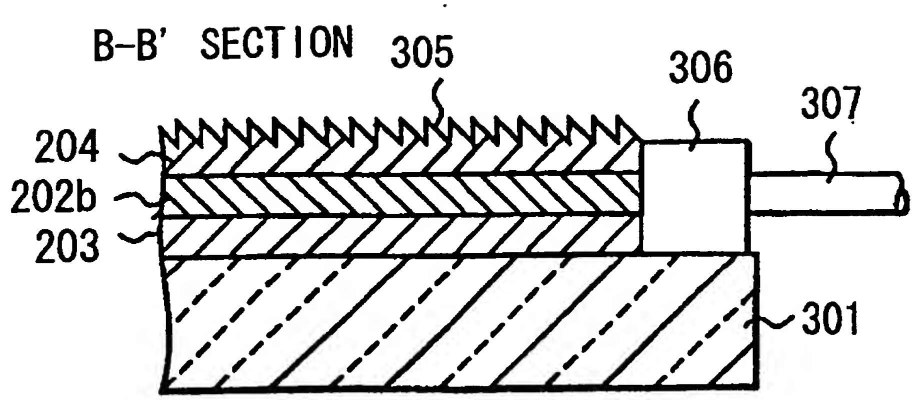

B-B' SECTION
305
306
307
204
202b
203
301

FIG. 8

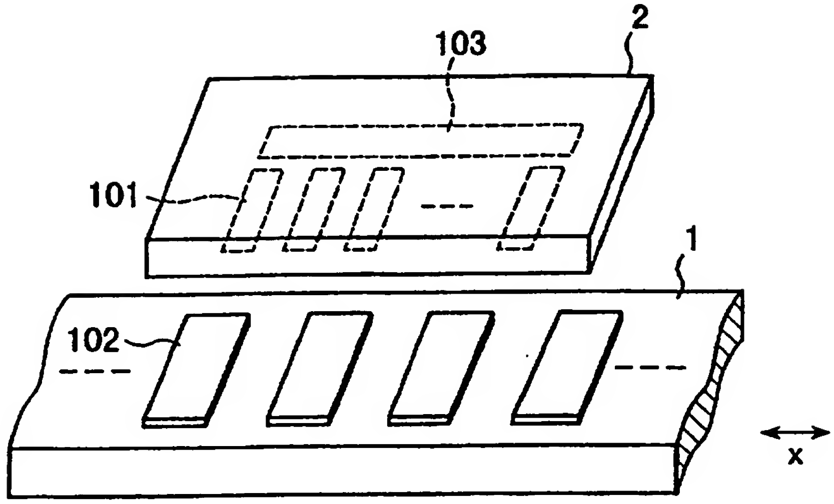

2
103
101
1
102
x

FIG. 9

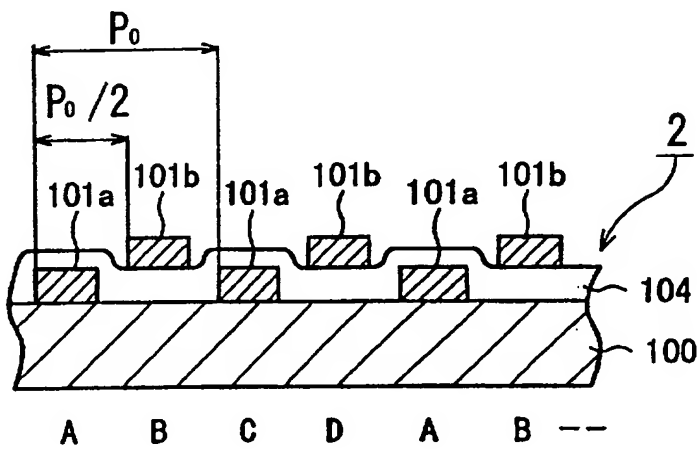

P_0
$P_0/2$
101a
101b
101a
101b
101a
101b
2
104
100
A
B
C
D
A
B --

FIG. 10

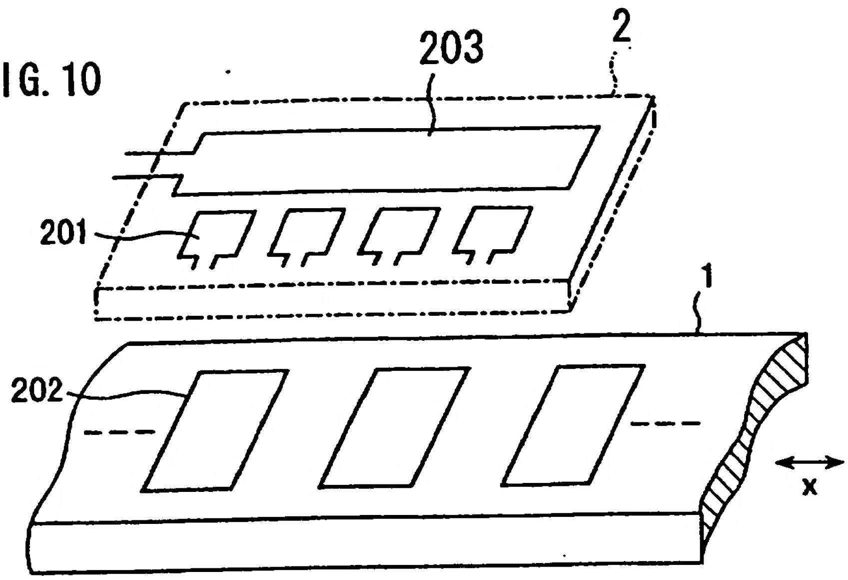
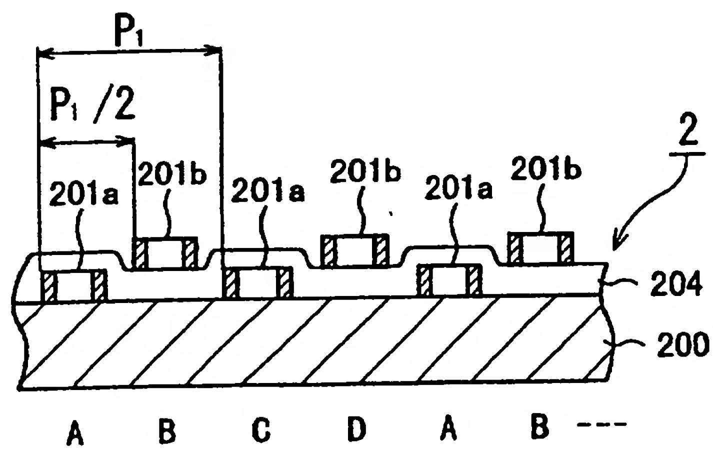

203
2
201
1
202
x

FIG. 11


P1
P1 /2
201a
201b
201a
201b
201a
201b
2
204
200
A
B
C
D
A
B ---

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DISPLACEMENT MEASURING APPARATUS

The present invention relates to a displacement measuring apparatus such a photoelectric encoder.

A known photoelectric encoder employs a photodetector array that includes photodetectors formed in an array with a certain pitch in relation to scale gratings and that serves as index gratings at the photodetective side. For example, when the scale gratings are arranged with a pitch of P, at least four photodetectors (one set) arranged with a pitch of P/4 are possible to provide displacement signals of quadrature-phase A, AB, B, BB with a phase difference of 90° from each other. If the scale gratings have a smaller pitch P and it is hard to form a photodetector array with the pitch of P/4, an array pitch of 3P/4 may be employed for the photodetector array, for example. Thus, displacement signals of quadrature-phase A, BB, B, AB with a phase difference of 270° from each other can be obtained in an array order of the photodetector array.

If the scale gratings have a much smaller pitch in a level of μm, however, it is not easy to form a photodetector array. In particular, when the photodetector array is produced through processing films of semiconductor such as amorphous silicon deposited on a substrate, a line/space ratio closes to the minimum process size, which causes a short circuit between phases and reduces a yield. In addition, attachment of dirt and dust onto the space also causes the short circuit even if a fine line/space ratio can be processed.

The present invention has been made in consideration of the above situation and accordingly has an object to provide a photoelectric encoder with an improved yield and reliability by processing a line/space ratio with a sufficient margin to realize a photodetector array having a substantially fine array pitch.

Another object of the present invention is to provide a displacement measuring apparatus having transmission devices arrayed with a substantially fine pitch for use in encoders of other types such as capacitive and magnetic types.

The present invention is provided with a displacement measuring apparatus, which comprises a scale member having scale gratings formed thereon with a certain pitch along a measurement axis, and a sensor head, movably arranged relative to the

scale member along the measurement axis, for reading the scale gratings. The sensor head includes a light source for emitting lights to the scale member, and a photodetector array for detecting lights from the scale member to output a plurality of displacement signals with different phases. The photodetector array includes a substrate, a first photodetector group formed in a first-layered semiconductor thin film disposed on the substrate, and an insulator for covering the first photodetector group. The photodetector array also includes a second photodetector group, formed in a second-layered semiconductor thin film disposed on the insulator, for receiving lights transmitted through spaces between photodetectors in the first photodetector group.

According to the present invention, the photodetector array employs semiconductor thin films in different layers on the substrate to form the first photodetector group and the second photodetector group disposed above the spaces in the first photodetector group. Accordingly, the entire photodetector array has a half pitch relative to the pitch, with which the first and the photodetector groups are formed. Thus, a line/space ratio in the photodetector array can be processed with a sufficient margin, thereby improving the yield and reliability of the photoelectric encoder.

Specifically, in the present invention, the substrate of the photodetector array comprises a transparent substrate. The first and second photodetector groups are layered and formed on a surface of the transparent substrate, which surface is opposite to the surface facing on the scale member.

In this case, the first and second photodetector groups was a lower common electrode formed of a transparent conductive film, for all photodetectors; and upper terminal electrodes formed, for individual photodetectors.

Also in the present invention, the first photodetector group may include at least one pair of photodetectors for outputting displacement signals of A- and AB-phases, which are 180° phase-shifted with each other in relation to the scale gratings. The second photodetector group may also include at least one pair of photodetectors for outputting displacement signals of B- and BB-phases which have phase differences of 90° from the A- and AB-phases, respectively.

In this case, the array pitch of the photodetectors in the first- and second photodetector group is $(n + 1/2)P$ (P: a pitch of the scale gratings, n: an integer, $n \geqq 1$).

Alternatively, the first photodetector group may include at least one pair of photodetectors for outputting displacement signals of A- and B-phases, which are 90° phase-shifted with each other in relation to the scale gratings. The second photodetector group may also include at least one pair of photodetectors for outputting displacement signals of AB- and BB-phases which have phase differences of 180° from the A- and

B-phases, respectively.

In this case, the array pitch of the photodetectors in the first- and second photodetector group is (n + 1/4)P (P: a pitch of the scale gratings, n: an integer, $n \geqq 1$).

Further in the present invention, the first photodetector group includes first and second sub-groups, each consisting of a plurality of photodetectors, for outputting displacement signals of A- and B-phases. A-phase has a phase difference of 90° from B-phase in relation to the scale gratings. The second photodetector group includes a first photodetector having a photodetective surface covering a region of the first sub-group, for outputting a displacement signal of AB-phase opposite to A-phase. The second photodetector group also includes a second photodetector having a photodetective surface covering a region of the second sub-group, for outputting a displacement signal of BB-phase opposite to B-phase.

Yet further in the present invention, the first photodetector group may include photodetectors connected in parallel to each other for outputting the displacement signal of A-phase. The second photodetector group includes photodetectors connected in parallel to each other for outputting the displacement signal of B-phase with a phase difference of 90° from A-phase. The apparatus further comprises a third photodetector group formed in a third-layered semiconductor thin film disposed on the second photodetector group via an insulator. The third photodetector group includes photodetectors connected in parallel to each other for outputting the displacement signal of AB-phase opposite to A-phase. The apparatus also comprises a fourth photodetector group formed in a fourth-layered semiconductor thin film disposed on the third photodetector group via an insulator. The fourth photodetector group includes photodetectors connected in parallel to each other for outputting the displacement signal of BB-phase opposite to B-phase.

The present invention is also provided with a displacement measuring apparatus, which comprises a scale member having signal transfer sections formed thereon with a certain pitch along a measurement axis, and a sensor head movably arranged relative to the scale member along the measurement axis. The sensor head includes a transmitter section for transmitting signals to the signal transfer sections, and a receiver section for receiving signals transferred from the signal transfer sections in the scale member. The transmitter section of the sensor head includes a substrate; first transmission devices arrayed and formed on the substrate; an insulator for covering the first transmission devices; and second transmission devices arrayed and formed on the insulator and having a phase difference from the first transmission devices.

The present invention is further provided with a displacement measuring

apparatus, which comprises a scale member having scale gratings formed thereon with a certain pitch along a measurement axis, and a sensor head, movably arranged relative to the scale member along the measurement axis, for reading the scale gratings. The sensor head includes a light source for emitting lights to the scale member, and a photodetector array for detecting lights from the scale member to output a plurality of displacement signals with different phases. The photodetector array includes a substrate; a first waveguide group, formed on the substrate, for receiving lights from the scale member and transferring them as optical signals; and a clad layer for covering the first waveguide group. The photodetector array also includes a second waveguide group, formed on the clad layer, for receiving lights transmitted through spaces between waveguides in the first waveguide group and transferring them as optical signals.

The present invention is effective also in the photodetector array that employs waveguides for simply receiving and transferring lights instead of active photodetector devices. In this case, the first waveguide group and the second waveguide group are laminated via the clad layer and arrayed with a 1/2-pitch difference from each other. This structure can reduce the pitch in the whole photodetector array.

Further, in the present invention, the transmission devices can be arrayed substantially with a fine pitch in an electrostatic capacitive encoder and a magnetic encoder, thereby achieving a high-resolution property. Specifically, (a) the signals may be transferred through capacitive couplings between the transmitter section and the signal transfer sections and between the signal transfer sections and the receiver section. In this case, the first and second transmission devices comprise transmission electrodes. Alternatively, (b) the signals may be transferred through magnetic couplings between the transmitter section and the signal transfer sections and between the signal transfer sections and the receiver section. In this case, the first and second transmission devices comprise transmission windings.

The present invention will be more fully understood from the following detailed description with reference to the accompanying drawings in which:

Fig. 1A shows an arrangement of a photoelectric encoder according to a first embodiment of the present invention;

Fig. 1B is a cross sectional view taken along an A-A' line in Fig. 1A;

Fig. 2A shows an arrangement of a photodetector array in the above

embodiment;

Fig. 2B is a cross sectional view taken along a B-B' line in Fig. 2A;

Fig. 2C shows an arrangement of an another photodetector array in the above embodiment;

Fig. 2D is a cross sectional view taken along a B-B' line in Fig. 2C;

Fig. 3 shows an arrangement of a photodetector array in a photoelectric encoder according to a second embodiment of the present invention;

Fig. 4 shows an arrangement of a photodetector array in a photoelectric encoder according to a third embodiment of the present invention;

Fig. 5 shows an arrangement of a photodetector array in a photoelectric encoder according to a fourth embodiment of the present invention;

Fig. 6 shows an arrangement of a photodetector array in a photoelectric encoder according to a fifth embodiment of the present invention;

Fig. 7A is a cross sectional view showing a sectional structure of the photodetector array in the above embodiment taken along an A-A' line in Fig. 6;

Fig. 7B is a cross sectional view showing a sectional structure of the photodetector array in the above embodiment taken along a B-B' line in Fig. 6;

Fig. 8 shows an arrangement of a capacitive encoder according to a sixth embodiment of the present invention;

Fig. 9 is a cross sectional view showing an array of transmission electrodes in the above capacitive encoder;

Fig. 10 shows an arrangement of a magnetic encoder according to a seventh embodiment of the present invention; and

Fig. 11 is a cross sectional view showing an array of transmission windings in the above magnetic encoder.

FIRST EMBODIMENT

Figs. 1A-B are a plan view of a photoelectric encoder according to a first embodiment of the present invention and a cross sectional view taken along an A-A' line thereof. The photoelectric encoder comprises a scale member 1 and a sensor head 2. The sensor head 2 is arranged opposite to and apart a certain gap from the scale member 1 and relatively movable along a measurement axis x of the scale member 1 to read scale gratings.

The scale member 1 includes scale gratings 11 arrayed and formed on a substrate 10 such as a glass substrate with a certain pitch P. Specifically in this

embodiment, the scale member 1 is of reflective type and the scale gratings 11 have an array of alternate reflective and non-reflective portions.

The sensor head 2 comprises an LED 3 as a light source, an index scale 4 for modulating output lights emitted from the LED 3 to illuminate the scale member 1, and a photodetector array 5 for receiving reflected lights from the scale member 1 to output displacement signals.

The index scale 4 comprises index gratings 41 arrayed and formed on a transparent substrate such a glass substrate with the same pitch as that of the scale gratings 11, for example. The photodetector array 5 includes photodetectors 51 formed from thin films of semiconductor such as amorphous silicon on a transparent substrate 50 such a glass substrate with a certain pitch in relation to the scale gratings 11.

Figs. 2A-B are a plan view showing a specific arrangement of the photodetector array 5 and a cross sectional view taken along a B-B' line thereof. As illustrated, the photodetector array 5 comprises, on the transparent substrate 50, a first photodetector group 51a and a second photodetector group 51b laminated in two separate layers. The first photodetector group 51a includes amorphous silicon photodiodes 22 arrayed and formed on a transparent conductive film 21 such as an ITO film that is formed as a common electrode on the transparent substrate 50. Each of photodiodes 22 specifically includes a laminated film consisting of a p-layer, an i-layer and an n-layer, sequentially deposited on the transparent substrate 50, and a terminal electrode 23 on the upper surface of the laminated film. The terminal electrode 23 is a Ni electrode.

The first photodetector group 51a can be produced through the following processes. First, the transparent conductive film 21 is formed on the transparent substrate 50, then p-, i- and n-layers of amorphous silicon films are deposited in turn on the transparent conductive film 21, followed by deposition of a Ni film on the upper surface of the amorphous silicon films. Next, the Ni film is patterned through a lithography process. The amorphous silicon films are then etched using a mask of the patterned Ni electrodes to separate individual photodiodes.

Thus formed first photodetector group 51a is covered with an insulator 24 such as a silicon oxide. Preferably, the upper surface of the insulator 24 is planarized. Thereafter, a second common electrode or transparent conductive film 25 is formed on the insulator 24. Amorphous silicon photodiodes 26 for the second photodetector group 51b are formed on the transparent conductive film 25. Terminal electrodes 27 are formed on the upper surfaces of these photodiodes 26. The structure of the second photodetector group 51b and the method of producing the same are similar to those of

the first photodetector group 51a. The upper surface of the second photodetector group 51b is covered with an insulator 28 for passivation.

The photodetector array 5, in this embodiment, receives lights from the transparent substrate 50. That is, the reflected lights from the scale member 1 enter the first photodetector group 51a via the transparent substrate 50. The lights passed through the transparent substrate 50 and then spaces in the first photodetector group 51a enter the second photodetector group 51b.

In the photodetector array 5 of this embodiment, the first and second photodetector groups 51a and 51b include photodetectors arrayed with a certain pitch to output quadrature-phase displacement signals. Specifically, in the first photodetector group 51a, photodetectors are arrayed with a pitch of 3P/2, where P is the pitch of the scale gratings. In the second photodetector group 51b, photodetectors are arrayed with a pitch of 3P/2 but shifted by a pitch of 3P/4 from the first photodetector group 51a. When quadrature-phase displacement signals with a phase difference 90° from each other are defined as A-, B-, AB- and BB-phases, the terminal electrodes in the first photodetector group 51a are alternately connected to a signal line 31a for A-phase and a signal line 31c for AB-phase. The terminal electrodes in the second photodetector group 51b are alternately connected to a signal line 31b for BB-phase and a signal line 31d for B-phase. As a result, the photodetector array 5 is possible to generate displacement signals of A-, BB-, AB-, B-phases with a difference of 3P/4 pitch (= 270 °) from each other.

As obvious from the above, the photodetector array 5 is configured from the first photodetector group 51a and the second photodetector group 51b, which are formed in different layers. Accordingly, the first and the second photodetector groups 51a and 51b have an array pitch double that of the photodetector array 5. This structure realizes an easier processing with a sufficient margin under a small scale grating pitch P and improves the yield and reliability of the photodetector array.

Figs. 2C-D are a plan view showing a specific arrangement of an another photodetector array 5' and a cross sectional view taken along a B-B' line thereof.In this case, as illustrated, the terminal electrodes in the first photodetector group 51a are alternately connected to a signal line 31a for A-phase and a signal line 31d for B-phase. The terminal electrodes in the second photodetector group 51b are alternately connected to a signal line 31c for AB-phase and a signal line 31b for BB-phase. Specifically, in the first photodetector group 51a, photodetectors are arrayed with a pitch of 5P/4. In the second photodetector group 51b, photodetectors are arrayed with a pitch of 5P/4 but shifted by a pitch of P/2 from the first photodetector group 51a. As a result, the

photodetector array 5' is possible to generate displacement signals of A-, AB-, B-, BB-phases with a difference of 3P/4 pitch (= 270 °) from each other.

This structure realizes an easier processing with a sufficient margin under a small scale grating pitch P and improves the yield and reliability of the photodetector array further more.

SECOND EMBODIMENT

If the scale grating pitch P is larger, the array pitch of the photodetector array 5 can be designed to P/4, for example. Fig. 3 shows, corresponding to Fig. 2A, such layout for a photodetector array 5 of a second embodiment, which has the same sectional structure as that in the first embodiment. In this case, as shown in Fig. 3, the first and second photodetector groups 51a and 51b are determined to have a pitch difference of P/4 from each other, and photodetectors in these groups are arrayed and formed with a pitch of P/2. Thus, from the photodetector array 5, containing the first and second photodetector groups 51a and 51b, quadrature-phase displacement signals of A, B, AB and BB-phases with a phase difference of 90° from each other can be obtained in the array order.

The photodetector array 5 in this embodiment also has a double-layered structure. Thus, the practical pitch for device processing is double the device array pitch finally obtained, improving the yield and reliability of the photodetector array.

In the preceding embodiments, the first and second photodetector groups 51a and 51b are exemplified as to have a line/space ratio not equal to 1/1 because a space is processed slightly larger than a line. The line/space ratio may be designed to 1/1 in order to array photodetectors with no interval between them in the entire photodetector array.

THIRD EMBODIMENT

Fig. 4 shows a sectional structure of a photodetector array 5 in a photoelectric encoder according to a third embodiment. In the present embodiment, the first photodetector group 51a and the second photodetector group 51b are formed in turn on the transparent substrate 50 similar to the first embodiment. Then, a third photodetector group 51c and a fourth photodetector group 51d are layered in turn on these photodetector groups 51a and 51b. An insulator 41 is employed for isolating the layers of the photodetector groups 51a, 51b, 51c and 51d from each other similar to the preceding embodiments.

Each of the first through fourth photodetector groups 51a-d has a plurality of

photodetectors that are arrayed with a pitch of P and connected in parallel to each other. These photodetector groups 51a-d are formed in such a manner that they have a phase difference of P/4 from each other, thereby outputting displacement signals of A, B, AB and BB-phases.

This structure ensures a large space between adjacent devices on processing each photodetector group to obtain an array of devices with a pitch of P/4 in the entire photodetector array, and can be employed to produce a photoelectric encoder having fine scale gratings with a high yield.

FOURTH EMBODIMENT

Fig. 5 shows a sectional structure of a photodetector array 5 in a photoelectric encoder according to a fourth embodiment. In this embodiment, the first photodetector group 51a formed on the transparent substrate 50 includes a first sub-group 51aa consisting of a plurality of photodiodes 22a arrayed with a pitch of P; and a second sub-group 51ab consisting of a plurality of photodiodes 22b arrayed with the same pitch. The first sub-group 51aa and the second sub-group 51ab are formed in such a state that they have a phase difference of 90° from each other. For A-phase, the plurality of the photodiodes 22a in the first sub-group 51aa are connected in parallel to each other; and for B-phase, the plurality of the photodiodes 22b in the first sub-group 51ab are connected in parallel to each other.

The second photodetector group 51b, layered on the first photodetector group 51a via an insulator, includes two photodiodes 26a and 26b, which are formed so as to have photodetective surfaces for covering the entire first and second sub-groups 51aa and 51ab, respectively.

If the terminal electrodes on the photodiodes 22a and 22b do not allow lights to pass through them, the first photodetector group 51a serves as optical shield gratings. Thus, the photodiode 26a in the second photodetector group 51b receives transmitted lights through spaces between photodiodes 22a of the first sub-group 51aa in the first photodetector group 51a and outputs a displacement signal of AB-phase. The other photodiode 26b in the second photodetector group 51b receives transmitted lights through spaces between photodiodes 22b of the second sub-group 51ab in the first photodetector group 51a and outputs a displacement signal of BB-phase.

This embodiment is also possible to achieve the same effect as those in the preceding embodiments.

The photoelectric encoders according to the present invention are not limited to the above embodiments. As described above, the photodetector array in the preceding

embodiments employs a transparent substrate, and photodetectors are laminated and formed on a surface of the transparent substrate, opposite to the surface facing on the scale member, to receive transmitted lights through the transparent substrate. Nevertheless, the surface for receiving lights may be one, on which the photodetectors are laminated. In this case, if a metal is employed for the terminal electrodes on the photodetectors, the terminal electrodes and the transparent common electrode must be turned upside down. In addition, the substrate is not required transparent.

Although the apparatus for obtaining quadrature-phase displacement signals are described in the above embodiments, the present invention can be applied similarly to a photoelectric encoder for obtaining tertiary-phase displacement signals with a phase difference of 120° from each other.

FIFTH EMBODIMENT

Fig. 6 shows an arrangement of another photodetector array 5a corresponding to the photodetector array 5 in the first embodiment. Simple optical waveguides 302a and 302b with no active regions are employed herein for photodetectors. Figs. 7A-B are cross sectional views taken along A-A' and B-B' lines in Fig. 6. The optical waveguides 302a and 302b are plane waveguides (core layers) formed by depositing and etching thin films.

The first waveguides 302a are arrayed with a pitch of 3P/2 on a substrate 301 and buried in a clad layer 303. The second waveguides 302b are arrayed on the clad layer 303 with a 1/2-pitch difference from the array of the first waveguides 302a. Another clad layer 304 is formed on the second waveguides 302b. These waveguides 302a and 302b are shaped into stripes, which extend along a direction perpendicular to the measurement axis of the scale, and arranged in parallel to the substrate 301. Lights from the scale are coupled not to an end surface of the waveguide but to a surface perpendicular to the end surface.

Specifically in this embodiment, lights are coupled to the outer surface of the clad layer 304 and introduced into the waveguides 302a and 302b therethrough. For this purpose, gratings 305 are formed as an optical coupler in the outer surface of the upper clad layer 304 to introduce the lights efficiently into the waveguides 302a and 302b. The gratings 305 can be formed through exposure of interference fringes and the clad layer etching.

Thus formed gratings 305 can diffract lights, which are assumed to enter from the scale in a direction substantially normal to the substrate 301 as shown in the section of Fig. 7B, with an angle θ into the clad layer 304, and allows them to couple to the

waveguides 302a and 302b. The angle θ is represented by dsinθ = mλ (d: a grating pitch, λ: a light source wavelength, θ: an integer).

If the substrate 301 is transparent, lights may enter the waveguides 302a and 302b through the substrate 301.

A bundle of optical fibers 307 is connected to one of end portions of the waveguides 302a and 302b via a connector 306. The bundle of optical fibers 307 is employed for an optical transmission path 308 to transfer optical signals obtained from the waveguides 302a and 302b to a measuring apparatus not depicted.

The waveguides 302a and 302b are formed in a double-layered structure and arrayed with a pitch of 3P/4, where P is the scale pitch for the entire. Four waveguides configure a set to obtain quadrature-phase optical signals of A-, BB-, B- and AB-phases.

As well in this embodiment, the double-layered structure of the waveguides for constructing the photodetector array is useful to obtain an array of photodetectors with such a fine pitch as half the practical process pitch.

Although two layers of waveguides are enough at least to effect, more layers of waveguides may be laminated similar to the embodiment shown in Fig. 4.

SIXTH EMBODIMENT

Figs. 8-9 show an embodiment, which is an application of the present invention to a capacitive encoder. The capacitive encoder comprises a scale member 1 and a sensor head 2 opposing to the scale member, similar to the photoelectric encoder. On the scale member 1, transfer electrodes 102 are arranged and formed with a certain pitch. Disposed on the sensor head 2 are transmitter electrodes 101 and a receiver electrode 103, which capacitvely couple with the transfer electrodes 102. The transmitter electrodes 101 are arranged with a certain pitch in relation to the transfer electrodes 102 arrayed on the scale member 1.

The array of the transmitter electrodes 101 comprises, as shown in the cross sectional view of Fig. 9, first transmitter electrodes 101a arrayed on a substrate 100, and second transmitter electrodes 101b arrayed thereon via an interlayer insulator 104. The second transmitter electrodes 101b are disposed on spaces between the arrayed first transmitter electrodes 101a to configure quadrature-phase transmitter electrodes with different phases of A, B, C and D as shown in Fig. 9, for example.

In this embodiment, plural transmitter electrodes are arranged in two separate layers to achieve a pitch of P0/2 for the total transmitter electrodes, where P0 is an array pitch for transmitter electrodes in each layer. Thus, an array of electrodes with a fine

pitch can be obtained.

SEVENTH EMBODIMENT

Figs. 10-11 show an embodiment, which is an application of the present invention to a magnetic (inductive) encoder. The magnetic encoder comprises a scale member 1 and a sensor head 2 opposing to the scale member, similar to the photoelectric encoder. On the scale member 1, transfer windings 202 are arranged and formed with a certain pitch. Disposed on the sensor head 2 are transmitter windings 201 and a receiver winding 203, which magnetically couple with the transfer windings 202. The transmitter windings 201 are arranged with a certain pitch in relation to the transfer windings 202 arrayed on the scale member 1.

The array of the transmitter electrodes 201 comprises, as shown in the cross sectional view of Fig. 11, first transmitter windings 201a arrayed on a substrate 200, and second transmitter windings 201b arrayed thereon via an interlayer insulator 204. The second transmitter windings 201b are disposed on spaces between the arrayed first transmitter windings 201a to configure quadrature-phase transmitter windings with different phases of A, B, C and D as shown in Fig. 11, for example.

In this embodiment, plural transmitter windings are arranged in two separate layers to achieve a pitch of P1/2 for the total transmitter windings, where P1 is an array pitch for transmitter windings in each layer. Thus, an array of windings with a fine pitch can be obtained.

As obvious from the above, according to the present invention, through the formation of a photodetector array with multi-layered photodetector groups, a photoelectric encoder with an improved yield and reliability can be obtained by processing a line/space ratio with a sufficient margin to realize a photodetector array having a substantially fine array pitch.

In addition, according to the present invention, with the use of a double-layered structure for the transmission device array of the transmitter sections in the sensor head opposing to the scale member, a displacement measuring apparatus having transmission devices arrayed with a substantially fine pitch can be obtained in an electrostatic capacitive or magnetic encoder.

CLAIMS

1. A displacement measuring apparatus, comprising:

a scale member having scale gratings formed thereon with a certain pitch along a measurement axis; and

a sensor head, movably arranged relative to said scale member along said measurement axis, for reading said scale gratings, said sensor head including:

a light source for emitting lights to said scale member; and

a photodetector array for detecting lights from said scale member to output a plurality of displacement signals with different phases, wherein said photodetector array includes:

a substrate;

a first photodetector group formed in a first-layered semiconductor thin film disposed on said substrate;

an insulator for covering said first photodetector group; and

a second photodetector group, formed in a second-layered semiconductor thin film disposed on said insulator, for receiving lights transmitted through spaces between photodetectors in said first photodetector group.

2. The displacement measuring apparatus according to claim 1, wherein said substrate is a transparent substrate, said first and second photodetector groups being layered and formed on one surface of said transparent substrate, the other surface facing on said scale member.

3. The displacement measuring apparatus according to claim 2, wherein each of said first and second photodetector groups as a lower common electrode formed of a transparent conductive film, for all photodetectors; and upper terminal electrodes formed, for individual photodetectors.

4. Apparatus according to any of claims 1 to 3, wherein said first photodetector group includes at least one pair of photodetectors for outputting displacement signals of A- and AB-phases, which are 180° phase-shifted with each other in relation to said scale gratings, and wherein said second photodetector group includes at least one pair of photodetectors for outputting displacement signals of B- and BB-phases, said B- and BB-phases having a phase difference of 90° from said A- and AB-phases, respectively.

5. Apparatus according to any of claims 1 to 3, wherein said first photodetector group includes at least one pair of photodetectors for outputting displacement signals of A- and B-phases, which are 90° phase-shifted with each other in relation to said scale gratings, and wherein said second photodetector group includes at least one pair of photodetectors for outputting displacement signals of AB- and BB-phases, said AB- and BB-phases having a phase difference of 180° from said A- and B-phases, respectively.

6. Apparatus according to any of claims 1 to 3, wherein said first photodetector group includes a first and second sub-groups, each consisting of a plurality of photodetectors, for outputting displacement signals of A- and B-phases, said A-phase having a phase difference of 90° from said B-phase in relation to said scale gratings, said second photodetector group including:

a first photodetector having a photodetective surface covering a region of said first sub-group, for outputting a displacement signal of AB-phase opposite to A-phase; and

a second photodetector having a photodetective surface covering a region of said second sub-group, for outputting a displacement signal of BB-phase opposite to B-phase.

7. Apparatus according to any of claims 1 to 3, wherein said first photodetector group includes photodetectors connected in parallel to each other for outputting said displacement signal of A-phase, and wherein said second photodetector group includes photodetectors connected in parallel to each other for outputting said displacement signal of B-phase with a phase difference of 90° from A-phase, said apparatus further comprising:

a third photodetector group formed in a third-layered semiconductor thin film disposed on said second photodetector group via an insulator, said third photodetector group including photodetectors connected in parallel to each other for outputting said displacement signal of AB-phase opposite to A-phase; and

a fourth photodetector group formed in a fourth-layered semiconductor thin film disposed on said third photodetector group via an insulator, said fourth photodetector group including photodetectors connected in parallel to each other for outputting said displacement signal of BB-phase opposite to B-phase.

8. A displacement measuring apparatus, comprising:

a scale member having signal transfer sections formed thereon with a certain pitch along a measurement axis; and

a sensor head movably arranged relative to said scale member along said measurement axis, said sensor head including:

a transmitter section for transmitting signals to said signal transfer sections; and

a receiver section for receiving signals transferred from said signal transfer sections in said scale member, wherein said transmitter section of said sensor head includes:

a substrate;

first transmission devices arrayed and formed on said substrate;

an insulator for covering said first transmission devices; and

second transmission devices arrayed and formed on said insulator and having a phase difference from said first transmission devices.

9. The displacement measuring apparatus according to claim 8, wherein said signals are transferred through capacitive couplings between said transmitter section and said signal transfer sections and between said signal transfer sections and said receiver section, and wherein said first and second transmission devices comprise transmission electrodes.

10. The displacement measuring apparatus according to claim 8, wherein said signals are transferred through magnetic couplings between said transmitter section and said signal transfer sections and between said signal transfer sections and said receiver section, and wherein said first and second transmission devices comprise transmission windings.

11. A displacement measuring apparatus, comprising:

a scale member having scale gratings formed thereon with a certain pitch along a measurement axis; and

a sensor head, movably arranged relative to said scale member along said measurement axis, for reading said scale gratings, said sensor head including:

a light source for emitting lights to said scale member; and

a photodetector array for detecting lights from said scale member to output a plurality of displacement signals with different phases, wherein said photodetector array includes:

a substrate;

a first waveguide group, formed on said substrate, for receiving lights from said scale member and transferring them as optical signals;

a clad layer for covering said first waveguide group; and

a second waveguide group, formed on said clad layer, for receiving lights transmitted through spaces between waveguides in said first waveguide group and transferring them as optical signals.

12. A displacement measuring apparatus substantially as hereinbefore described with reference to any of the examples shown in the accompanying drawings.

INVESTOR IN PEOPLE

Application No: GB 0018962.1
Claims searched: All

Examiner: Bob Clark
Date of search: 16 November 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): G1A(AEAL, AEAX); G1N (NACNC, NAEDR)

Int Cl (Ed.7): G01D 5/20, 5/22, 5/24, 5/241, 5/34, 5/347, 5/36

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2078966 A (MEYER)	
A	EP 0814317 A1 (SELF DEVELOPMENT)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.